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Review Article

Forest Waste Management and Technology

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A B S T R A C T

Today's world is facing a very big problem of increasing waste and how to manage this waste. This waste has many source points, like household (plastic packaging wrappers, plastic bottles, bags, straws, electronic waste, etc.) and industrial (hazardous materials and chemical water), etc. Scientists, foundations, and companies around the world try to solve this problem with the help of innovative technologies to slow down the process. What once was just household or workplace waste has now made its way into our forests. Increasing the amount of waste is a very crucial thing for us to think about and prevent as soon as possible. Forest waste can significantly increase the risk of forest fires by acting as fuel. This review paper shows some technology to prevent forest waste and how to manage waste in forest areas.

Keywords: Forest Waste, Waste Management, Forest Fire, Technology, Prevention of Waste

Introduction

Waste production is directly related to human activities.[1] Municipal waste is produced by every human being. Their number and variety of waste grow every year. In addition to municipal waste, the second group consists of industrial waste,[2] i.e., waste related to the activities of enterprises. Due to economic development and the improvement of living conditions in society, the amount of waste is also increasing.[3] This increase in waste is not only part of human life, but it now interrupts nature's life cycle and also significantly increases in forest areas. This waste in forests can be increased by tourists, campers and illegal dumping of waste in forest areas. Forest waste indirectly increases the risk of forest fires by acting as a fuel. "Man-made waste not only pollutes the forest—it turns it into a ticking time bomb for fire." The aim of this review paper is to discuss the possibility of using modern technologies in the waste management sector. The number of new technologies in the waste management sector is considerable. Here we presented some of them, which seem to be the key in modern waste management. In this overview research studies and commercial technologies are covered.

Why Forest waste Management is Crucial

The Forest Service receives millions of visitors each year to day-use areas and campground recreation sites. The high number of visitors means that large quantities of solid waste must be disposed of in a safe and cost-effective way. Our "throw-away" society lifestyle has contributed significantly to the tremendous increase of solid waste, especially in the packaging of everyday products. According to the 1989 U.S. Congress Office of Technology Assessment document OTAO-424, food packaging is designed to meet multiple purposes, including the following.

1. Protection of products during shipping and maintaining a longer shelf life
2. Prevention of food spoilage
3. Display of consumer information
4. Compliance with government regulations
5. Tamper prevention
6. Theft prevention
7. Consumer convenience
8. Attractive packaging presentation

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Many of these products find their way to national forest lands and into a solid waste management programme.

Environmental Protection Agency (EPA) statistics show an average person can generate up to four pounds of waste per day. This amount may vary depending on a person's activity, but the fact still remains that in an average week, a family of four generates approximately 12 pounds of garbage each day.[1] There is no official data about how many tonnes of garbage are collected in the Forest area.

- **Total waste generation:** In 2020-21, India generated 160,038.9 tonnes of solid waste daily.
- **Waste collection:** 152,749.5 tonnes of waste were collected daily, representing a collection efficiency of 95.4%.
- **Untreated waste:** 50,655.4 tonnes of waste, or 31.7% of the total generated, remained unaccounted for in 2020-21. A significant portion of this unmanaged waste likely ends up in natural environments, including forests.
- **Waste Composition:** Almost 50% of India's waste is organic, with the remainder divided into recyclable and biomedical/hazardous waste (table 1).

Table 1.Forest waste classification (Man made)

Waste Category	Description
Rigid plastic Packaging	Plastic bottles, containers, jars, tubs used for pack
Flexible plastic packaging	Wrappers, bags, sachets, cling film, plastic sheets
Multi-layered plastic packaging	Laminates combining plastic, aluminium or paper
Composable plastic packaging	Bio-degradable or composable carry bags
Glass waste	Beverage bottles, broken glass, jars
Rubber wear/ Footwear	Torn slippers, rubber soles, tires

Overview of Technology

Waste management technologies have evolved in recent years, motivated by the desire to minimise the environmental impact of waste and enhance the effectiveness of waste management procedures. There is a wide range of approaches, ranging from conventional techniques like composting or landfilling to modern, more advanced solutions using IOT technologies.[4]

Smart Bin

The smart bin system is the solution that makes the environment better and decreases the stress of waste management in human beings. It is equipped with many sensors and technologies to help manage waste more effectively. These sensors can detect a very large range of data, like the fill level of the bin, humidity, weight, gas emission produced by the waste and much more. The more efficient method of controlling the waste material filling level is using an ultrasonic sensor which measures the current fill level by measuring the distance between the top of the bin and the bottom of the bin, and after measuring the fill level, the microcontroller compares this value with the waste bin fill capacity because it can send the notification to its worker or some authorities. Also, the smart bin includes flame and humidity sensors which predict an upcoming fire or harmful events.[3] Being IoT devices, sensors can communicate with other devices or systems. We should take care of software also that will handle all this information and store data for more analysis, like descriptive analysis, predictive analysis, and prescriptive analysis, so all the data which is collected from various sensors needs to be stored in a database.[5]

Making more efficient smart bins and setting up the GPS tracking system are becoming prevalent things in waste management. There are many IoT technologies which are used for smart bins to network. Here is the network which is most commonly used:

LoRaWAN (Low Power Wide Area Network): it is a wireless communication protocol that is being used for low-range, low-power IoT applications. This network protocol is best for smart bins due to long-range data transmission, and its power consumption is very low.

Bluetooth: It is used for short-range data transmission, and Bluetooth is not applicable for large-scale applications due to its limited range. It is used by workers to maintain the system in case of system failure. But also, it is the safest transferring network compared to the other network systems.

MQTT (Message Queuing Telemetry Transport): It is the lightweight messaging protocol that is designed for low-power IoT applications. This network works with TCP/IP for data communication and has very strong delivery guarantees.

Here in figure 1, it shows that the waste bin, which contains the sensors like the ultrasonic sensor, humidity sensors, gas sensors, and any other sensor, communicates with the end device, and the server acts as an intermediary between them.

"BinScape" is the intelligent smart bin system which integrates an intelligent system to effectively manage waste (Figure 2). There are 3 significant features in this system that could manage waste more effectively and efficiently. First is automated waste classification, which is classifying captured waste images and using a programmed algorithm

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to make classification decisions. Second is that automated waste detection allows the smart bin to sense the waste and perform a sorting technique after gaining the result of classification. Third is the dashboard provided to allow the client user to monitor the activity and all operations and visualise the database to retrieve data.[4]

The core hardware in the system is Raspberry Pi and other specifications, and it also includes a 5MP camera model for image capturing and classification of the image. And other components like proximity sensors.

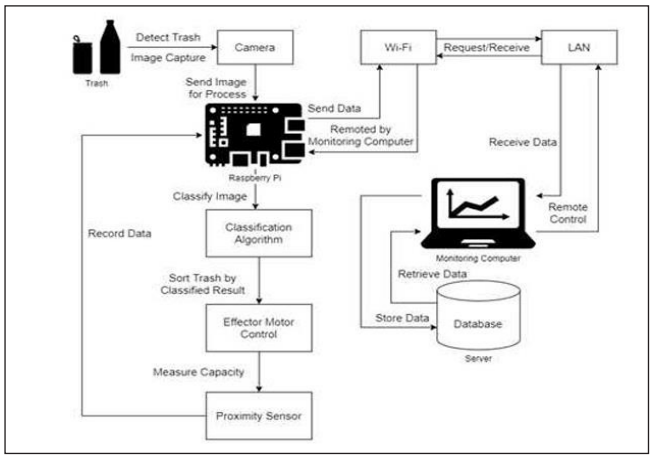

Figure 1.IoT based Smart Bin Waste Collection

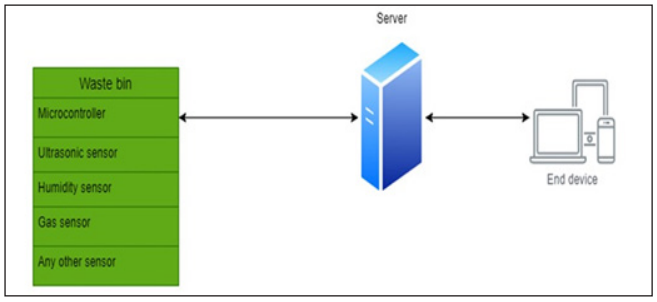

Figure 2.BinScape Architecture

Automated Waste Classification

This used a computer vision application programming interface (API), which is open-source computer vision (OpenCV) and used with a deep learning algorithm.

Automated Waste Detections and Sorting

Only automated waste classification is not enough; there is a requirement for a robotic system which is implemented to give instructions without humans and to perform waste sorting. The sensors are sensing the distance between the object and the proximity sensor. Using these sensors, the user has no need to open and close manually. Sorting depends on the rotation of the motors. When people throw some trash, then servo motors will release and change the dropping channel with a specific rotation degree. Using the sorting method will reduce the human efforts to do waste sorting manually.

Interactive Dashboard

A dashboard is also important to interact with an automation system with a user or client because a smart bin system cannot rely on only automation. It is also important to do a statistical analysis report and data recovery for further future analysis.[4]

Green Bot

A Green Bot is the concept that combines robotics and smart technologies which helps to sort and recycle waste and manage waste efficiently. Green Bot can be used in homes, public places, factories and forests.[5]

Key Feature of the Green Bot:

- **IoT Integration:** It gives alerts services to the municipality when the bin is full.
- Green Bot stays connected to the cloud 24/7 to send real-time data about waste levels and waste materials.
- **Automated Collections:** Green Bot is equipped with suction systems and robotic arms to drop and pick up the waste materials.
- **Solar Powered:** Green Bot is run on a solar-powered system to reduce the carbon footprint.
- **Smart Waste Segregation:** It uses AI technology and sensors (e.g., moisture, metal detectors, IR) and separates biodegradable, hazardous and recyclable waste.
- **Voice commands or touchscreen:** Using voice commands Green Bot is easy to use, or we can operate it using mobile or any other electronic devices.

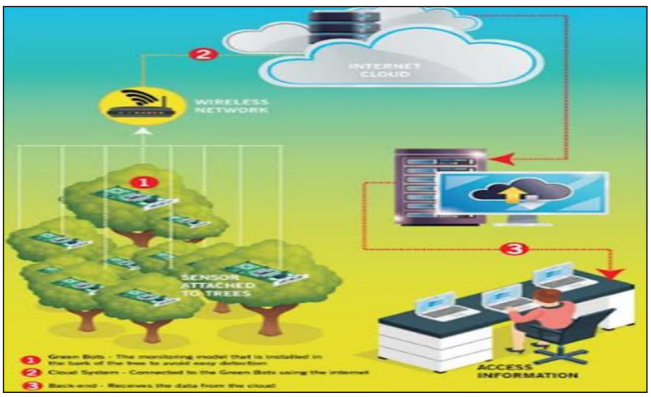

Figure 3.Green bot[7]

Cost-Efficient

This model is very cost-effective, and Green Bot is suitable for homes, societies, and educational institutions and is also used for forest waste management.

Modular Design

- It is easy to assemble, upgrade or maintain.
- New components like sensors can be added also easily.
- Bins can be cleaned easily and separated.

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By Drone Technology

Certain areas within the forest are not suitable for manual or continuous work due to the presence and movement of wild animals, posing risks to human safety.

A drone-based waste collection system in forest areas can revolutionise environmental management by utilising AI-powered drones equipped with cameras, LiDAR, and GPS to detect and map scattered waste across dense terrain. These drones, capable of vertical takeoff and carrying lightweight collection bins or robotic grippers, can either autonomously collect visible trash or transport bins to designated hotspots where visitors can deposit waste. Supported by solar-powered charging hubs, mesh communication networks, and GIS-based heatmaps, the system enables continuous monitoring and optimised routing even in GPS-limited environments.

Integration with a mobile app allows the public to report litter, gamifying the process and encouraging responsible tourism, while the collected waste is transported to centralised eco-stations for sorting and recycling. This approach ensures minimal ecological disruption, enhances forest cleanliness, and offers a scalable, sustainable solution for remote waste management.

Limitations in India's deployment of forest garbage collection technology

While the potential to address forest garbage pollution exists, several factors hinder the effective deployment of collection technology and related solutions in India:

Geographical Challenges

- **Inaccessible terrain:** Many forested areas in India are remote and difficult to access, posing significant logistical challenges for deploying and operating advanced collection technologies like specialised vehicles or machinery.
- **Lack of infrastructure:** Even where the terrain is somewhat accessible, a deficiency of basic infrastructure like motorable roads and designated collection points impedes efficient waste collection and transport.
- **Dispersed waste:** Man-made forest garbage, often originating from tourism, pilgrimages, or dumping, can be scattered over wide areas, requiring extensive and resource-intensive collection efforts.

Financial constraints and policy gaps

- **Limited budgets:** Local bodies, responsible for waste management, often operate with insufficient funding, making it difficult to invest in advanced collection technologies and infrastructure improvements.

Figure 4.Drone equipped with a LiDAR and camera payload conducting aerial survey operations over agricultural and forested landscapes[8]

Source[yellowscan.com]

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- **Lack of financial incentives:** The absence of robust financial incentives or sustainable funding mechanisms can deter the adoption of innovative technologies or attract private sector investment in forest waste management.
- **Policy implementation gaps:** Despite progressive policies like the Solid Waste Management Rules, 2016, and the Swachh Bharat Mission (SBM), implementation at the local level remains inconsistent due to a lack of technical expertise, enforcement, and public participation.
- **Unclear responsibilities:** Unclear demarcation of responsibilities and limited accountability among various stakeholders can hinder the development and enforcement of effective waste management strategies.

Behavioral and social barriers

- **Lack of public awareness and participation:** Limited awareness about proper waste segregation, the environmental impact of littering, and the importance of responsible disposal among communities and visitors in forest areas remains a significant obstacle.
- **Resistance to change:** Overcoming established habits and traditional practices related to waste disposal can be challenging, requiring sustained awareness campaigns and community engagement efforts.

Conclusion

The increasing generation of waste from households, industries, and other human activities has now extended into forests, creating serious environmental and ecological challenges. Forest waste not only disturbs the natural ecosystem but also poses a severe threat by acting as fuel and increasing the risk of forest fires. Addressing this problem requires immediate attention and sustainable solutions. Innovative technologies, coupled with scientific research and community participation, provide promising approaches to manage and reduce forest waste effectively. Waste segregation at source, recycling methods, smart collection systems, and the integration of drones and robots for monitoring can significantly minimise its harmful impact. By adopting these solutions at both local and global levels, we can move towards a cleaner environment, protect our forests, and ensure ecological balance for future generations.

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References

1. Jasrotia A, Maheshwari A, Ngelambong A, Singh P. Implementing Sustainable Waste Disposal Solutions in Rural Touristic Regions: A Case Study of Spiti Valley, Himachal Pradesh. InSolid Waste Management and Disposal Practices in Rural Tourism 2025 (pp. 383-394). IGI Global.
2. Biswas SN, Kumar P, editors. Mountain Tourism and Ecological Impacts: Himalayan Region and Beyond: Himalayan Region and Beyond. IGI Global; 2024 Mar 27.
3. Thakur TK, Eripogu KK, Thakur A, Kumar A, Bakshi S, Swamy SL, Bijalwan A, Kumar M. Disentangling forest dynamics for litter biomass production in a biosphere reserve in central India. Frontiers in Environmental Science. 2022 Jul 12;10:940614.
4. Singh R, Gehlot A, Akram SV, Thakur AK, Buddhi D, Das PK. Forest 4.0: Digitalization of forest using the Internet of Things (IoT). Journal of King Saud University-Computer and Information Sciences. 2022 Sep 1;34(8):5587-601.
5. Shah A. Modern technology for sustainable forest management in India. Observer Research Foundation. 2020 Jul 15;382:1-4.
6. Aithal PS. Smart city waste management through ICT and IoT driven solution. International Journal of Applied Engineering and Management Letters (IJAEML). 2021 May 6;5(1):51-65.
7. Lam KN, Huynh NH, Ngoc NB, Nhu TT, Thao NT, Hao PH, Kiet VV, Huynh BX, Kalita J. Using artificial intelligence and IoT for constructing a smart trash bin. InInternational Conference on Future Data and Security Engineering 2021 Nov 14 (pp. 427-435). Singapore: Springer Singapore.
8. Zhao M, Ye RJ, Chen ST, Chen YC, Chen ZY. Realization of forest internet of things using wireless network communication technology of low-power wide-area network. Sensors. 2023 May 16;23(10):4809.

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